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Performance studies for the prototype III of CASTOR forward calorimeter at the CMS experiment

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Abstract

We present preliminary results of the performance of prototype III of the CASTOR quartz-tungsten sampling calorimeter, to be installed in the very forward region of the CMS experiment at the LHC. The energy linearity and resolution, as well as the spatial resolution of the prototype to electromagnetic and hadronic showers are studied with E= 10-200 GeV electrons, E= 20-350 GeV pions, and E= 50, 150 GeV muons in beam tests carried out at CERN/SPS in 2007.

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1 Introduction

The CASTOR (Centauro And STrange Object Research) detector is a quartz-tungsten sampling calorimeter, which will be installed in the CMS experiment at 14.38 m from the interaction point, covering the pseudorapidity range $5.1 < \eta < 6.6$. The detector will contribute mainly to forward QCD studies (diffractive, low-x) and cosmic-rays-related physics and “exotica” in both proton-proton [1] and heavy-ion [2] collisions at LHC energies. The results of the beam test and simulation studies with CASTOR prototype I [3] and prototype II [4] allowed us to define a third prototype. The beam tests were carried out in the H2 line at CERN Super Proton Synchrotron (SPS). The prototype was one full-length octant, consisting of the electromagnetic (EM) and hadronic (HAD) sections, with a total of 28 readout-units (RUs) constructed with successive layers of tungsten (W) plates as absorber and fused silica quartz (Q) plates as active medium (see Fig. 1). The Čerenkov light, produced by the passage of relativistic particles through the quartz medium, is collected in sections of 5 W/Q layers along the length of the calorimeter and focused by air-core light guides onto PMTs. For the EM section, the W-plates have a thickness of 5 mm and the Q-plates 2 mm. For the HAD section, the W- and Q-plates have a larger thicknesses of 10 mm and 4 mm, respectively. The plates are inclined 45^o with respect to the direction of the impinging particles, in order to maximise the Čerenkov light output. The EM section is divided in two successive RUs and has a total of 20.12 X_0 (0.77 λ_I lengths). The HAD section has 12 RUs, corresponding to 9.24 λ_I. In total, the CASTOR prototype has $\approx 10\ \lambda_I$.

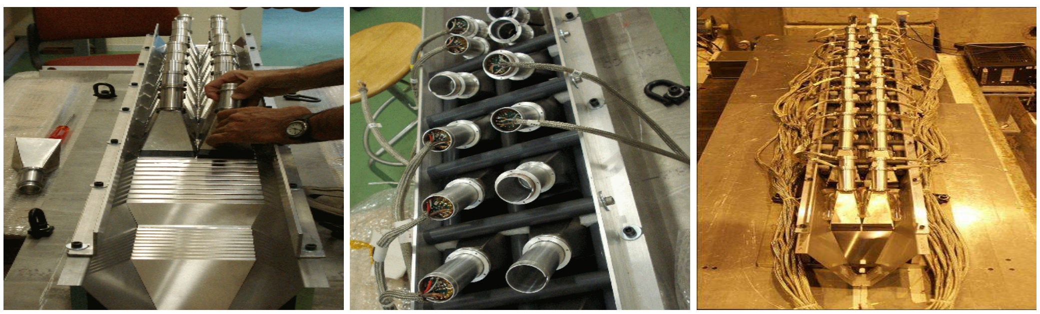

Figure 1: Photograph of successive stages of the octant calorimeter assembly with W/Q-plates, air-core light guides and PMTs (left & middle) and the fully instrumented octant prototype (right).

2 Response to muons

Muon energy spectra at 50 and 150 GeV were measured in the EM and HAD sections. Figure 2 shows the muon peaks measured for the 150 GeV beam. The good pedestal-MIP separation allowed us to use the muon signal for the intercalibration of different channels of the CASTOR prototype.

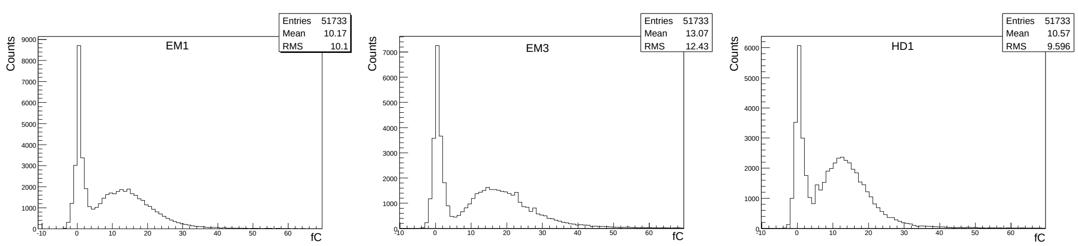

Figure 2: Energy spectra measured in the two EM and first HAD sections of the final CASTOR prototype with a muon beam of 150 GeV energy. The pedestal peak is clearly separated from the muon signal.

3 Response to electrons

The electromagnetic energy resolution and linearity were studied with electron beams of energy 10-200 GeV. An example of an electron signal peak is shown in Figure 3 (left) for a beam of 80 GeV.

The peak signal position is plotted as a function of the beam energy in Figure 4 (left). The calorimeter response is found to be linear in the energy range explored. The relative energy resolution of the calorimeter was also studied by plotting the normalised width of the Gaussian signal amplitudes with respect to the incident beam

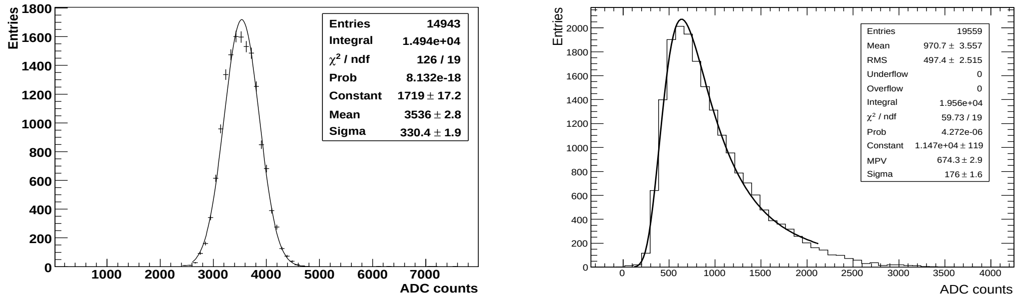

Figure 3: Response of the calorimeter to 80 GeV electrons (left) and 80 GeV pions (right). The spectra are fitted by a Gaussian and Landau distribution respectively.

electron energy and fitting with the functional form $\sigma_E/E = p_0 + p_1/\sqrt{E}$ (Fig. 4, right). An area scanning of

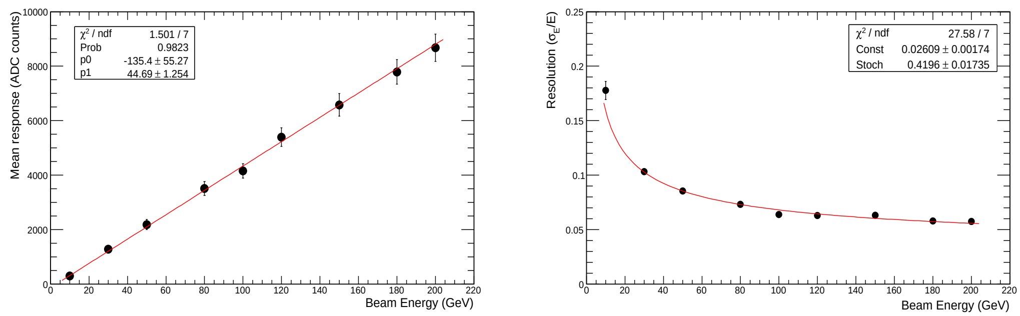

Figure 4: Energy response linearity (left) and energy resolution (right) of the EM sections.

the calorimeter was also performed in order to estimate the width of the EM shower profile (Fig. 5, right). The x-derivative of the response was calculated, giving the width of the electromagnetic shower of $\sigma = 1.15$ mm.

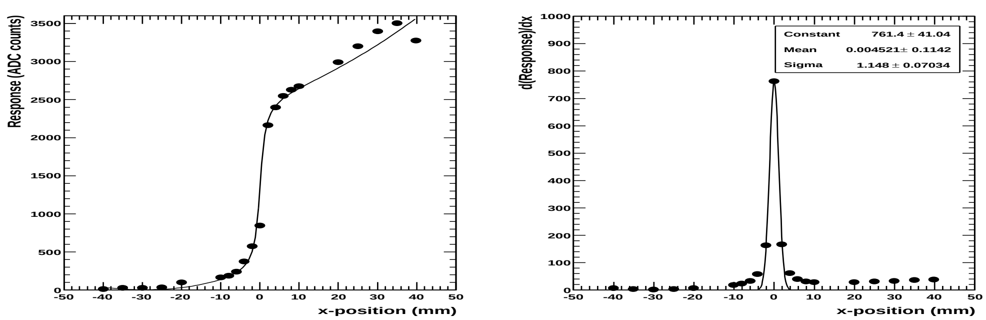

Figure 5: Response of the right semi-octant of the EM section as the beam scans the front face of the calorimeter. The derivative of the response with respect to x, indicates the width of the EM shower.

4 Response to pions

Pions of energy 20-350 GeV were used for the study of the hadronic response of the prototype. An example of a pion signal peak is shown in Figure 3 (right) for a beam of 80 GeV. The peak of the total pion energy measured by the prototype was found to be well fitted with a convoluted Gaussian and Landau curve. The hadronic energy linearity and resolution were obtained by fitting the spectrum measured for all beam energies and is shown in Figure 6. The spatial response of the prototype calorimeter to pions was obtained from 2 EM and 6 HAD RUs, by moving the beam along the x-direction.

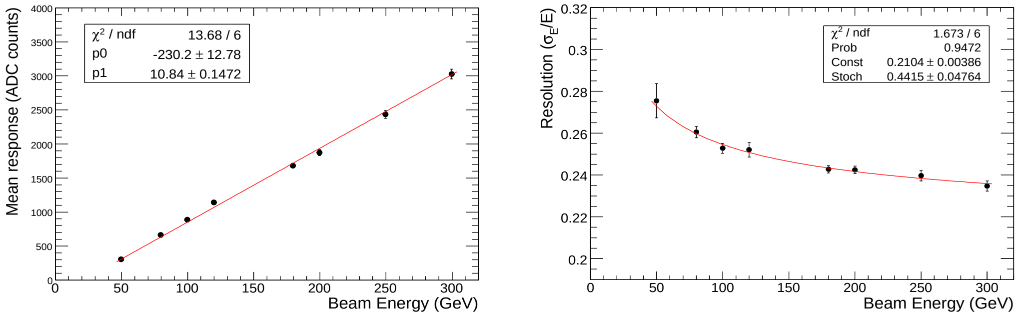

Figure 6: Response linearity (left) and energy resolution (right) of the hadronic sections.

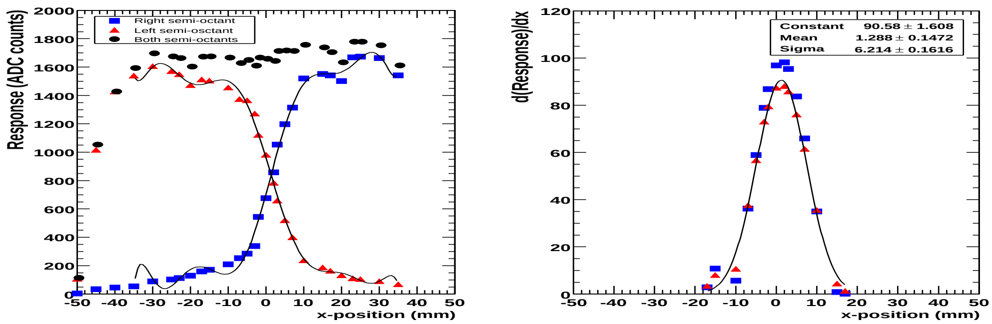

Figure 7: Response of the hadronic section as the beam scans the front face of the calorimeter. The derivative of the response with respect to x, indicates the width of the hadronic shower.

5 Summary

The main conclusions of this study can be summarised as follows:

- The PMTs feature a good pedestal-MIP separation. This allows one to use the muon signals to obtain the intercalibration coefficients of the different channels.
- The EM section of the calorimeter shows a good energy linearity. The resolution of the EM section is characterised by a stochastic term of $\approx 41\%$ and the constant term is around 3%. The width of a typical EM shower is $\approx 1.15\ mm$.
- The full calorimeter (10 λ_I) shows a good energy linearity for hadronic showers. The measured stochastic (constant) term of the resolution is around $44\%(21\%)$. The width of a typical pion shower is $\approx 6.2\ mm$.

6 Acknowledgments

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